Why do Software Firms Fail?
Capabilities, Competitive Actions and Firm Survival in the Software Industry from 1995 to 2007

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This study examines why firms fail or survive in the volatile software industry. We provide a novel perspective by considering how software firms' capabilities and their competitive actions affect their ultimate survival. Drawing on the resource based view (RBV) we conceptualize capabilities as a firm's ability to efficiently transform input resources into outputs, relative to its peers. We define three critical capabilities of software producing firms: Research and Development (RD), Marketing (MK) and Operations (OP), and hypothesize that in the dynamic, high technology software industry, RD and MK capabilities are most important for firm survival. We then draw on the competitive dynamics literature to theorize that competitive actions distinguished by a greater emphasis on innovation-related moves will increase firm survival more than those emphasizing resource-related moves. Finally, we postulate that firms' capabilities will complement their competitive actions in affecting firm survival. Our empirical evaluation examines a cross-sectional, time series panel of 5,827 observations on 870 software companies from 1995 to 2007. We use a stochastic frontier production function to measure the capability for each software firm in each time period. We then use the Cox proportional hazard regression technique to relate capabilities and competitive actions to software firms' failure rates. Unexpectedly, our results reveal that higher OP capability increases software firm survival more than higher MK and RD capabilities. Further, firms with a greater emphasis on innovation-related than resource-related competitive actions have a greater likelihood of survival and this likelihood increases even further when these firms have higher MK and OP capabilities. Additional analyses of sub-sectors within the software industry reveal that firms producing visual applications (e.g., graphical and video game software) have the highest MK capability but the lowest OP and RD capabilities and make twice as many innovation-related as resource-related moves. These firms have the highest market values but the worst Altman Z scores, suggesting that the firms are valued highly but also are at high risk for failure, and indeed the firms in this sector fail at a greater rate than expected. In contrast, firms producing traditional decision-support applications and infrastructure software have different capabilities and make different competitive moves. Our findings suggest that the firms that persist and survive over the long term in the dynamic software industry are able to capitalize on their competitive actions due to their greater capabilities, and particularly, OP capabilities.

Keywords: Software Industry, Survival Analysis, Capability, Resource Based View, Marketing, Operations, Research & Development, Stochastic Frontier Production Function, Competitive Actions, Competitive Dynamics

1. **Introduction**

The software industry is a powerful wealth creator. It has experienced unrivaled job creation, extraordinary growth, and accelerated product cycles. Nevertheless, the software industry is also recognized for its volatility: failures in the industry can be spectacular. At the turn of the millennium, many once glamorous software companies filed for bankruptcy. Compared with firms in other knowledge-intensive industries, firms in the software industry have a very high rate of failure: 15.9% of firms in the software industry failed from 1995 to 2007, while 11.5% in computer hardware, and 4.7% in the pharmaceutical industry failed during the same time period. [1] Software is a prototypical "Schumpeterian" industry in which entry and exit barriers are low, marginal costs of production are minimal, product innovation occurs rapidly and disruptively, and firms' competencies and strategies are critical for competitive advantage (Schmalensee 2000; Giarratana and Fosfuri 2007). Indeed, software is an extremely "porous" industry: from 1995 to 2007, firms entered the software industry at 1.2 times the rate for pharmaceuticals and 2.2 times for computer hardware. In theory, any talented individual with a computer can enter the industry. But, due to its dynamic nature, surviving in the industry is a challenge; as Schmalensee puts it, "…leadership positions in software are often fragile" (2000, p. 193). In fact, from 1995 to 2007, firms exited the software industry at three times the rate of pharmaceuticals and twice of computer hardware firms. These interesting attributes motivate us to examine firm survival in the software industry. We ask: *why do some software firms fail while others survive*? *What helps to sustain the survival of software firms in the long term*?

It is important for Information Systems (IS) researchers to understand the dynamics of the software industry (Sawyer 2000). Firms in the software industry produce and sell software applications and related systems. Since software runs the computers and networks that support the flow of information in the global economy, the competition in the software industry affects firms in all other industries that use these products and services for their own competitive advantage. It is also important for researchers to study firm survival. Survival or long-term viability has always been recognized as a basic business objective

[1] These numbers are based on data on bankruptcies from Compustat and CRSP for the different industries from 1995-2007.

that is related to, but distinct from, firm financial performance (Dertouzos, et al. 1989). Survival is a prerequisite for market success and profitability (Lieberman, 1990; Dunne, et al., 1989). The research on firm survival has extensively studied industry-specific factors and firm demographic factors that correlate with survival (Manjòn-Antolín and Arauzo-Carod, 2008). However, there is less understanding of whether and how firms' competitive actions and competencies influence their odds of survival.

In this study, we theorize that a software firm's capabilities have a significant bearing on its survival. Following Dutta, et al. (2005) and Amit and Shoemaker (1993), we define a firm's *capability* as its relative efficiency in transforming inputs into desired outputs. For example, a firm's research and development (RD) capability measures the efficiency with which the firm can translate its RD spending into patented new software technologies, relative to its peers. We emphasize that large firms with high levels of outputs may not be more capable. Rather, the firm with a higher capability is the one that *converts* inputs into outputs efficiently, generating greater output *than its peers with respect to its level of input*. It is this *relative transformative efficiency* that we posit is essential to survival in the unpredictable software industry.

To illustrate, consider Peregrine Systems and Epicor Software. Both companies make enterprise software and have roughly comparable levels of sales and similar spending on RD. Peregrine Systems averaged over $183 million in annual sales from 1995 until the time it filed for bankruptcy in 2004 and spent 12% of its annual sales on RD. Epicor Software Corporation averaged $143 million in annual sales and also spent 12% of its annual sales on RD over the same time period. However, from 1999 to 2001, Peregrine grew its product line very rapidly, acquiring a new company every quarter. The company could not effectively assimilate the new technologies it acquired, and its ability to define and sustain a consistent product line suffered. We found that Peregrine Systems' RD capability declined 15% from 1995 to 2004 when the company filed for Chapter 11 bankruptcy. In contrast, over the same time period, we found that Epicor Software maintained its level of RD capability, improved its other capabilities and is thriving (named as one of FORTUNE magazine's 100 Fastest-Growing Companies in 2006).

We distinguish three primary capabilities of software firms: RD, marketing (MK) and operations (OP). As Keil and Carmel (1995) have pointed out, software firms are typically evaluated in terms of their revenues, profits and product reviews; these factors are closely associated with MK, OP and RD. Clearly, software firms are under constant pressure to innovate, which makes RD capability essential (Menor et al. 2007). MK capability is a very important factor for success in a competitive high-tech industry (Dutta et al. 1999). Finally, firms must be able to cost-effectively produce commercially viable software, implying that OP is another distinctive capability of software firms (Hayes and Upton, 1998). To understand why there are variations among software firms in their capabilities, we invoke a guiding firm-level theory: the resource-based view (RBV). The RBV regards a firm as a bundle of resources and suggests that resource deployments significantly affect a firm's competitiveness, and in turn its success or failure (Barney, 1991; Peteraf, 1993, Wernerfelt, 1984). Although the RBV and survival analysis have distinct foci, both have their roots in firm performance, and the two concepts can be linked together.

We also explore the relationship between competitive actions and survival. An example of a competitive action is the introduction of a new product. The literature has established how firms' actions affect their competitors, competitive advantage and performance (e.g., Chen, et al. 1992; Smith, et al. 2001; Ferrier, 2001; Young, et al. 1996). However, to the best of our knowledge, the relationship between firm *survival* and competitive actions has not been established. It is not clear whether traditional measures of firm performance (which are short term) will correlate with firm survival which reflects long term performance. This suggests the importance of investigating the relationship between firms' competitive actions and survival. Finally, we draw on theories of strategic alignment (Porter, 1996; Prahalad and Hamel, 1990; Hayes and Wheelwright, 1984) to posit that firms' capabilities will complement their competitive actions in affecting firm survival. Firms which have the ability to execute efficiently *and* the ability to act competitively to expand revenues will outperform firms that can only perform on one dimension (Mittal, et al. 2005). From this perspective, we posit a complementary relationship between firms' capabilities and competitive actions in their joint influence on firm survival.

We analyze a cross-sectional, time series panel of 5,827 observations of capabilities, competitive actions and firm demographics collected on 870 software companies from 1995-2007. We adopt stochastic translog production functions to estimate firms' capabilities and use Cox's proportional hazard (PH) model (Cox, 1972) to estimate the impact of capabilities and competitive actions on the probability that the firms will survive.

This research makes several contributions. First, we study firm survival. Survival is not commonly studied by Information Systems (IS) researchers. Yet, it is the "ultimate" measure of firm performance. It is related to but distinct from traditional firm performance and therefore merits study (Reimann, 1982). Further, although researchers have examined how firms' IT capabilities contribute to firm financial performance (e.g., Bharadwaj, 2000), the relationship between capabilities and *survival* has not been examined. Our study makes a contribution to the literature by providing insight into the link between firm capabilities and firm survival in the context of the software industry in which survival is quite challenging.

Second, we extend the approach of Dutta, et al. (2005) in conceptualizing and measuring firms' capabilities in terms of their relative efficiency in transforming inputs into outputs. An important critique of the RBV concerns the difficulty of assessing capabilities. By using a flexible stochastic translog production function, we are able to assess the transformative ability of each software firm to convert its input resources into critical outputs, relative to other firms in the industry. Our results highlight the importance of relative capability measures. Given the strength of our results, other researchers may more readily adopt the efficiency concept to assess firms' capabilities.

Third, our enhanced theoretical model integrates the RBV and competitive dynamics literatures, to theorize a relationship between firms' competitive actions and firm survival. To the best of our knowledge, evaluating the interactions between firms' capabilities, their competitive actions and subsequent survival or failure is a new contribution to the literature. By incorporating competitive actions in our model, we endeavor to respond to the call by Smith, et al. (2001) to further explore the interactions between firm resources, actions and performance.

Finally, our findings enrich the research on the software industry, and reveal whether (and which) capabilities and competitive actions help software firms to survive over the long term. Despite the critical role of software firms in producing the digital systems for global information economy, the software industry has been surprisingly understudied in the Information Systems (IS) literature. Our study thus has the potential to spark future research on the software industry by IS researchers.

In the next section, we discuss the important characteristics of our research context: the software industry. §3 presents our research model and hypotheses and §4 describes the data, measurement, and analytical techniques used to test our hypotheses. §5 presents the statistical analyses and results, and the discussion and concluding remarks are given in §6.

2. The Software Industry

The software industry (SIC code 7372) creates and markets software that performs functions such as desktop productivity suites, enterprise resource planning systems, customer relationship management systems, business intelligence tools, video games, statistical software, operating systems and security software, with almost $300 billion in annual sales. After rapid growth in the late 1990s, the software market posted only a 0.6% revenue gain in 2001 and a decline in 2002 due to weak enterprise and consumer IT spending (Bokhari 2007). However, growth has since resumed at an 8% rate. While some segments (e.g., enterprise software) grew rapidly in the 1990's, they are now relatively mature; other new segments (e.g., business intelligence tools) are currently experiencing double-digit growth rates.

According to industry experts, the software industry is segmented horizontally by layers – a primary segmentation is between applications and infrastructure software (Bokhari 2007), each of which accounts for half of the industry's sales. Infrastructure software includes the basic systems needed to operate the computer hardware and networks, including operating systems, data center management tools, application design and development tools, application life-cycle management, application development platforms, and middleware. Applications software performs specific end user functions. The industry embraces different sub-segments that focus on different types of applications such as visual applications (e.g., video games, graphics, and entertainment systems), and traditional decision support applications (e.g., enterprise resource planning systems, customer relationship management, statistical analysis, financial reporting and word processing). Firms in different segments have encountered different levels of technology maturity and face different competitive dynamics (Bokhari 2007).

A key feature of the software industry concerns the length of product life cycles. The length of each product's life cycle varies depending on its function and market. For example, video game software has a short life cycle, while operating systems and traditional decision support applications have longer product life cycles. RD investments are essential for new product development and existing product enhancement. Given the software industry's rapid rate of technological change, RD is especially important in influencing the product's life cycle. To remain competitive, software firms often invest in high levels of RD spending. In fact, RD expenditures of as much as 20% of revenues are common in the software industry – a considerably higher percentage than for most other industries (Bokhari 2007).[2]

There are intense competitive dynamics in the software industry. Firms producing mature products like basic desktop applications usually form an oligopoly market where a few well-established software firms such as Microsoft and Oracle capture significant market share. These firms are "entrenched" and have large installed bases of customers who may be reluctant to switch to a competing product due to transaction costs. Even if a new firm's product is superior, the established firm can upgrade and enhance its product to match the features. In addition, customers may believe that an established firm is likely to remain in business while a software start-up might fail, leaving customers with product enhancement and support problems. For all of these reasons, it can be challenging for new entrants to compete with established firms in the more mature segments. However, new software firms can thrive in new segments. For example, during the period of our study (1995-2007), new entrants such as Red Hat created novel software applications for sale over the Internet. Many new firms made initial public offerings (IPOs) of common stock in the late 1990s, but many firms also went out of business during the technology sell-off in late 2000 through 2002. The software industry reached its peak in terms of the total number of firms in

[2] From 1995 to 2007, the software firms in our sample averaged 28.7% of their net sales spent on RD each year, with a minimum of 0% and a maximum of 34.6%. In contrast, computer hardware firms averaged 11.0% and pharmaceutical firms averaged 18.7% of their sales on RD during the same timeframe.

1998 (604 firms) and declined after 1998, stabilizing in 2003 in terms of failures. There are many new entrants to the software industry, but also many exits.

3. Research Model and Hypotheses

Figure 1 illustrates our research model and hypotheses. Our research model relates firm survival to firm capabilities and to firms' competitive actions, controlling for demographic factors. The following sections elaborate the logic and motivation of the constructs and relationships in the model.

3.1 Firm Survival

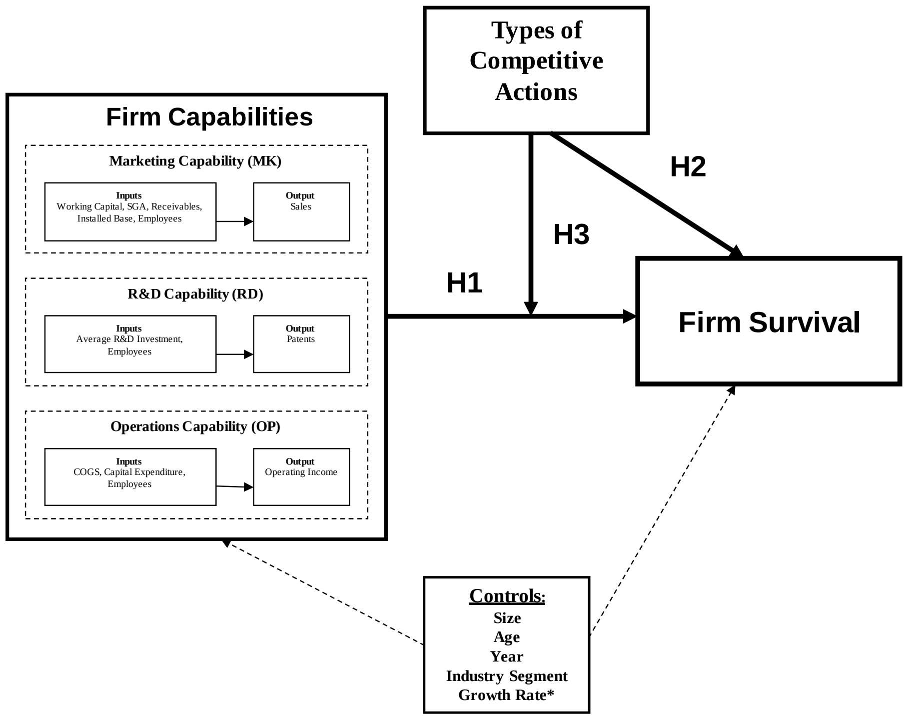
Firm survival is considered the ultimate criterion of organizational effectiveness (Reimann 1982). Hannan and Freeman (1988) and Suarez and Utterback (1995) define *survival* as the probability that a firm will continue operations rather than exit an industry.[3] Firm survival has been studied by researchers in various fields. See Manjòn-Antolín and Arauzo-Carod (2008) for a review. Numerous determinants have been postulated. In the following, we discuss aspects that are relevant to the software industry.

Population ecologists (e.g. Hannan and Freeman, 1988) study industry-specific factors and argue that firms entering a crowded or highly technological field, or in a later stage of product life cycle have a lower chance of survival. In high-tech industries such as software, firms tend to fail as their core technology becomes obsolete. While the software industry is in the growth stage of its life cycle (Bokhari 2007), some products are mature (e.g., mainframe computer software); for these products, a few firms with an established presence prevent newcomers from thriving.

Researchers have also examined the firm-specific factors that contribute to firm survival. Among them firm size and age are found significant, as newer or smaller firms generally have a higher likelihood of failure (Hall, 1987; Mata and Portugal, 1994) due to the superior resources and expertise of their larger or more mature competitors. However, in high technology industries such as software, such disadvantages are less pronounced, especially for firms that are able to produce a viable product (Audretsch, 1995) or that have large informal social networks (Raz and Gloor, 2007).

[3] In this study, we consider a firm to "fail" if it files for Chapter 7 or Chapter 11 bankruptcy and ceases operations.

Figure 1. Conceptual Framework.



Economists have studied the relationship between firm growth and survival. They find that, while mature firms can grow "proportionately" according to "Gibrat's Law", young firms must grow more quickly (disproportionately) to reach a minimum scale level to survive (Lotti, et al., 2003). Yet, it is hard for new firms to grow quickly and acquire the competence to mobilize resources to generate market returns (Garnsey, et al. 2006). The ability to grow quickly and effectively may therefore be a key factor for survival, given the rapid pace of technological change and the subsequent emergence of new markets.

One other key factor for firm survival in the software industry is the ability to innovate. Innovation enables a firm to create new products and markets, stimulating growth and financial stability, and thereby its survival. There is compelling evidence that product and process innovation is important for survival, since even incumbent firms must continuously innovate to mitigate the threat of disruption from new technologies (Christensen, 1997). Researchers have found that software firms with more innovative strategies for product versioning, bundling and portfolio broadening are more likely to survive (Cottrell and Nault, 2004; Giarrantana and Fosfuri, 2007; Mallick and Schroeder 2005; Christensen, et al. 1998).

Given firm characteristics (age, size) and industry distinctiveness (maturity, density, pace of change), what makes some software firms more “fit” and thereby more able to survive than others?

In the following, we posit that firms’ capabilities are critical for survival and that individual capabilities affect firm survival differently. We draw on the RBV to conceptualize software firms’ capabilities and then pose the relationships between firm capabilities, competitive actions and survival.

3.2 Software Firms’ Capabilities

The resource-based view (RBV) links firm performance to firm resources and capabilities. According to Wade and Hulland (2004), value, rarity and appropriability are resources that lead to *creation* of competitive advantage, while (Barney, 1991) argues that low imitability, substitutability and mobility help firms to *sustain* competitive advantage. Consistent with studies of high technology firms (Dutta, et al. 1999), we focus on RD, MK, and OP capabilities. We conceptualize and define each capability in terms of its input and output resources and describe how each capability has the critical attributes necessary to create or sustain competitive advantage for firms in the software industry.

RD Capability (RD): RD capability reflects a firm’s effectiveness in new idea generation and product/service development (Lumpkin and Dess, 1996; Kao, 1995). Firms with superior RD capability enjoy strong customer loyalty, brand recognition, competitive advantage, and premium price (Givon et al. 1995). RD often leads to prized rare products whose value can be appropriated by the producing firm. Since software development is a “learning by doing” task (Boh, et al. 2007), the acquired tacit knowledge about the product is difficult for competitors to substitute or imitate, at least in the short run.

RD expenditures are essential for creating products and technologies (Morbey and Reithner, 1990). Since software is a knowledge product (Slaughter, et al. 2006), a critical input to the software RD process includes employees who design new software or enhance and adapt the existing software products. Outputs of RD in a high tech industry are often reflected in the quality and quantity of patents (Hall, et al. 2005). Historically, computer algorithms are not patentable. However, in 1995 the *In re Beauregard* case opened up software patents opportunity, signaling the end of the U.S. Patent and Trademark Office

(USPTO)'s resistance to patent computer algorithms.[4] Since then, software patents have grown rapidly and now comprise 15% of all patents (Bessen and Hunt, 2007). A software firm that has a strong RD capability has the ability to efficiently convert its investments in RD into novel products (represented with patents). We thus define the following RD input/output transformation function:

RD capability = efficiency in converting RD input resources into RD outputs, where:

RD Output (Patents) = f(RD inputs (RD Expenditures, Employees, Controls))

Marketing Capability (MK): MK capability is the ability to identify customer needs and to understand consumer preferences (Day, 1994). Firms with superior MK capability are better at promoting and selling products and building more effective relationships with customers (Deshpande, et al. 1993). Such relationships are hard to imitate or transfer because they are firm-specific and tacit (Day 1994). These capabilities are also highly appropriable, as firms can capture sales revenues and establish brand recognition by effectively deploying marketing resources (Amit and Shoemaker, 1993).

MK capability is a transformative process that converts inputs into marketing related outputs. A primary goal of marketing is to increase sales revenue (Dutta, et al. 1999). For a software firm, sales revenue includes the income generated from software licenses, maintenance, and services (Bokhari, 2007). Resources needed to generate sales include expenses on sales force and product promotion (named Selling, General and Administrative expenses or SGA). In fact, SGA is one of the software industry's largest budget items (Fayad, et al. 2000; SoftLetter, 2003). There are other critical resources in marketing. First, installed base is particularly important, given the externalities and switching costs characterizing the industry (Brynjolfsson and Kemerer, 1996). Existing customers represent an important input for generating sales. Second, both accounts receivable and working capital provide readily available resources that the firm can use for marketing growth and expansion (Dutta, et al. 1999). Accounts receivable reflects the extension of credit to customers which can help the firm to complete sales for products (Bokhari 2007). Working capital provides liquid resources that can be deployed to generate

[4] Although patents were made available for software in 1995, guidelines were not clarified until 1998. It is possible that this legal uncertainty may have affected software firms' RD capability in the early years of our sample. However, we found no differences in mean RD capabilities across the different years of our study's time period.

future sales (Srinivasan and Hanssens, 2009). A final critical resource to marketing includes the employees who market, sell, produce and distribute the software products. The above discussion suggests:

MK capability = efficiency in converting MK input resources into MK outputs, where:

MK Output (Sales) = f(MK inputs (Selling, General and Administrative Expenses, Installed Base, Accounts Receivable, Working Capital, Employees, Controls))

Operations Capability (OP): OP capability refers to a firm's ability to use resources cost-effectively (Miller and Roth 1994). Firms gain an operating advantage by efficiently leveraging their resources to create operating income (Roth and Jackson, 1995). Operational efficiency creates value that cannot be easily substituted. Indeed, operational capabilities can be surprisingly robust in providing sustained competitive advantage (Hayes and Upton, 1998; Oliver, 1997). Highly firm-specific operational processes may be slow to diffuse as they often require substantial organizational adaptation. In terms of operations, the software industry is unique with gross margins as high as 80% (Bokhari, 2007). The variable cost of manufacturing, documenting, and packaging the product is relatively small (Shapiro and Varian 1998). The highest margins are on licenses for new software; gross margins for maintenance and especially for software services are considerably lower as training, consulting, implementation, support and other services are quite labor-intensive and require highly skilled individuals to perform them.

The primary OP output is operating income (Hendricks and Singhal, 2005), a result of a firm's ongoing operations. Regarding inputs, labor and capital are the two primary inputs in the operations function (Varian, 2002). Employees are key labor inputs (Carmel and Sawyer, 1998). Another input for operations is cost of goods sold (COGS), i.e., the cost needed to provide products or services to customers. Software developer's productivity can be greatly improved by the use of advanced tools (Slaughter, et al. 1998; Iivari, 1996; Banker and Kauffman, 1991) and processes (Harter, et al. (2000)) as using effective software development processes improves productivity, time to market and quality of the software produced. Thus, to be operationally efficient, software firms must invest in productivity-enhancing processes and tools, and this investment is captured in capital expenditures. We define the following:

OP capability = efficiency in converting OP input resources into OP outputs, where

OP Output (Operating Income) = f(OP inputs (Employees, COGS, Capital Expenditure, Controls))

3.3 Capabilities and Firm Survival

Capabilities transform inputs into more valuable outputs (Barney, 1991), while superior capabilities help firms gain competitive advantage (Ray et al. 2004). Indeed, capabilities are key determinants of firm financial performance (Dutta et al, 1999; Day, 1994; Irwin and Klenow, 1994; Bharadwaj, 2000). Since capabilities are often difficult to copy, having superior capabilities helps create and *sustain* competitive advantage (Wade and Hulland, 2004; Day 1994). A sustained competitive advantage is crucial for a firm's long-term viability and survival. This is particularly true for the software industry, where new technologies emerge unexpectedly, frequently and disruptively. In the mature segments of the software market, profit margins are low (Bokhari, 2007). A few established players can leverage economies of scale and their installed base to compete and survive. Small or new firms find it difficult to compete due to lack of the installed base of customers and the economy of scale to earn sufficient profits to survive. Thus, these firms must have the ability to innovate and create new technologies to capture market share in new market segments. This highlights the importance of firms' capabilities, and particularly capabilities which confer sustained competitive advantage to increase the odds of survival. In fact, Teece, et al. (1997) argued that to survive and thrive, firms' capabilities must be dynamic, i.e., having the capacity to continually renew their competences.

The literature suggests that some capabilities may afford more advantages than others in terms of their relative impacts on firm performance. For example, firms with active market research are more proactive and entrepreneurial (Lee et al. 2001); equipped with new products and services, these firms tend to be first movers, and often forge a new market segment or replace existing ones (Christensen, 1997). Wade and Hulland, (2004) theorize the extent to which different IS resources have the potential to create or sustain competitive advantage. We adapt their approach to assess software firms' RD, MK and OP capabilities in terms of their ability to create different levels of value, rarity, appropriability, imitability, substitutability and mobility – the key resource attributes from the RBV. All types of capabilities can help a software firm create competitive advantage. A firm with greater RD and MK capabilities will develop and market software products that are better suited to its customers, conferring the advantages of high value and rarity. Stronger OP capabilities help a firm to capture the rent or income from these innovative products, conferring high appropriability.

However, there are potential differences among the capabilities in terms of their potential to help a software firm *perpetuate* competitive advantage over a longer period of time. Although a first-mover advantage from a software product is hard to sustain (Clemons and Row, 1991, Kettinger, et al. 1994), a firm with superior RD capability can continually innovate and thereby sustain its leadership (e.g., Microsoft's office productivity suite, Oracle's database product). In fact, unique features of the software industry such as the strong presence of network effects and switching costs may help a software firm with a first mover advantage and superior RD and MK capabilities to sustain an initial competitive advantage (Brynjolfsson and Kemerer, 1996). Thus, greater RD and MK capabilities help a firm to not only create but also perpetuate its competitive advantage, increasing its chances of survival over the long term.

However, OP capabilities may have less potential to sustain competitive advantage for software firms. This is not because operational efficiency is not important. Rather, it is due to the greater potential for imitability, substitutability and mobility for operational resources. For example, a software firm could imitate competitors to achieve a higher OP capability by hiring skilled developers, and using effective software development tools and mature software development processes (Harter, et al. 2000). Firms that are operationally efficient, but that do not continually innovate and market new products or features will be at a competitive disadvantage with respect to its peers, as it will be competing in low margin segments of the software industry in which it can be very difficult to earn profits. Thus, from the perspective of the RBV, the ability of OP capabilities to sustain competitive advantage and thereby survival is lower than that of RD and MK capabilities.

Similarly, from the perspective of dynamic capabilities (Teece, 2007), higher OP capabilities help a firm to achieve "technical fitness", but not "evolutionary fitness". Technical fitness measures how effectively a capability performs its function regardless of whether the capability enables the firm to make a living, while evolutionary or external fitness measures how well the capability enables a firm to make a living (Helfat, et al. 2007). From this perspective, higher OP capabilities help a firm to execute its operations more efficiently and have greater technical fitness, but the ability to create new technologies and shape opportunities in new markets (such as afforded by greater MK and RD capabilities) helps a firm achieve the evolutionary fitness that is necessary for long term success. Therefore, we posit that:

Hypothesis 1: *Higher levels of MK and RD capabilities reduce firm failure rates more than higher levels of OP capability.*

3.4 Competitive Actions and Firm Survival

In their pursuit of competitive advantage, firms make offensive and defensive competitive moves such as introducing new products, launching a new marketing campaign, acquiring another company and hiring or firing workers. These actions position firms with respect to their rivals in their competitive environment (Chen, et al. 1992; Grimm and Smith, 1997), and competitive positioning determines firms' ultimate performance (Porter 1980).

The competitive dynamics literature has conceptualized different dimensions of competitive actions and has studied their antecedents and consequences. Smith, et al. (2001) contend that firms' competitive actions may be represented by: pricing, marketing, new product, capacity/scale, service and operations, etc. In our study, we aggregate the various types of moves into two basic types of competitive actions: innovation-related (including new product, pricing, and marketing actions) and resource-related (including operations and service, mergers, acquisitions, and other capacity/scale-related actions).

The competitive dynamics literature has not studied firm survival, *per se*, but the research has shown a strong link between competitive actions and firm performance. Specifically, firms exhibiting a greater intensity and complexity of actions, in a particular sequence, and with more aggressiveness have better profitability or market shares than their rivals (Ferrier, 2001; Ferrier, et al. 1999; Young, et al. 1996). In the software industry, there are some interesting dynamics that could influence the relationship between firms' competitive actions and survival. Since the industry is characterized by rapid, disruptive innovation, it is a "winner take all" industry with significant network effects such that the first mover is believed to have a competitive advantage that is difficult to beat (Shapiro and Varian, 1998). Following Teece (2007), we would expect that in this dynamic environment, firms initiating more innovation-related moves will be more likely to survive. That is, software firms that emphasize innovation-related moves increase their chances of survival because more effort is invested to create, promote and market new products, enhancing their "evolutionary fitness" for the dynamic software industry. Therefore:

Hypothesis 2: *Firms that initiate a greater proportion of innovation-related competitive actions are less likely to fail than firms that do not.*

3.5 Complementarities between Competitive Actions, Capabilities and Firm Survival

To sustain the competitive advantage achieved through competitive positioning, firms must align their internal activities and their external competitive actions (Porter 1996; Milgrom and Roberts, 1995; Hayes and Wheelwright, 1984). Alignment means that firms have activities and structures that complement their competitive actions (Farjoun, 2002). Internally and externally focused activities in firms can affect each other in ways that strengthen their joint effects (Prahalad and Hamel, 1990). Specifically, when internal activities and external actions are complementary, performing them together will lead to a higher outcome than if they were performed separately (Siggelkow, 2002). When activities are complementary, they mutually reinforce each other in a consistent way, and competitors cannot easily imitate them.

The logic of strategic alignment suggests that firms' capabilities and competitive actions are complementary in their effects on firm survival. That is, firms are better able to sustain a competitive advantage when they initiate competitive actions *and* when they can also efficiently execute these actions. In the dynamic software industry, we have drawn on the notion of "evolutionary fitness" (Teece, 2007; Helfat, et al. 2007) to theorize that firms will be better off, in terms of survival, when they initiate a greater proportion of innovation-related competitive actions. The literature on strategic alignment suggests that there are even greater benefits for long-term competitive advantage and firm survival when firms complement these innovation-related competitive actions with higher MK, OP and RD capabilities. Firms with stronger capabilities can deploy their resources effectively (Barney, 1991), i.e. quickly execute their competitive actions in a productive way. Higher capabilities *and* greater emphasis on innovation-related competitive actions should thus afford these firms even more opportunities to create new products as well as to generate more profits, increasing the likelihood of their survival even further. Therefore:

Hypothesis 3: *MK, OP and RD capabilities complement competitive actions such that firms initiating a greater proportion of innovation-related moves and that have higher levels of capabilities, will have even lower failure rates.*

3.6 Other Factors Affecting Firm Survival (Controls)

In addition to firm capabilities and competitive actions, we control for variables that have been shown to affect firm survival. The first one is firm size. Small software firms usually lack current assets or credit lines to effectively market their products (Gans, et al. 2002). They face a critical disadvantage before they evolve into full-fledged companies (Dollinger, 1995; Shrader and Simon, 1997). Another control variable is firm age. Klepper and Thompson (2006) showed that the likelihood of firm survival increases with firm age. In the software industry, first movers often have a significant advantage that they can exploit over time. Therefore, older firms with a longer history of success are more likely to survive.

We also control for firm growth, sector and performance. Hart and Prais (1956) pioneered the study of growth, followed by Hymer and Pashigian (1962), Mansfield (1962), Hall (1987), and Mata and Portugal (1994). More recently, Lotti (2007) and Lotti, et al. (2003) have concluded that the rate at which new firms grow matters more in shaping survival probability than initial size or age. We use employee growth to proxy firm growth, due to the importance of human capital in software firms. In terms of industry sub-sector, we control for segments in the software industry: traditional applications, visual applications, and infrastructure software. Product life cycles and competitive dynamics are quite different in each sub-sector, with visual applications having the shortest product life cycle, and infrastructure software the longest life cycle. Each firm is assigned to one sector, based on its primary product line. With respect to firm performance, since firm survival is influenced by financial performance, we control for each firm's Altman Z score, a measure of a firm's "fitness" (Altman, 1968).

Finally, we control for the effects of time. The time period under study encompasses the Internet boom and bust. In the Internet boom, venture capitalists supplied software firms with ample resources for growth and innovation, as evidenced by the large numbers of IPOs in the mid- to late 1990's (Bokhari, 2007). However, after bubble burst in 2000, the economic environment became more uncertain. The total number of failed software firms in the bust period is considerably more than that in the boom period. This suggests the need to control for time period in our study, and we incorporate a variable for each year.

4. Methodology

In this Section, we first describe our data sources and sample. We then describe the measures of the variables in our analysis. This is followed by a description of our approach to estimate firms' capability scores and our model of firm survival.

4.1 Data Sources and Sample

We constructed a data panel consisting of publicly owned software firms with a standard industry classification code (SIC) of 7372. This industry covers firms primarily engaged in the design, development, production and sale of computer software such as Microsoft, Oracle, Adobe, and RedHat. We collected data from various archival databases and websites as described below on software firms who filed 10-K reports with the SEC during 1995-2007. This time period is particularly well suited to a study of firm survival. The introduction of the Internet spurred many new entrants, but there were also many failures when the "boom" went "bust". Given our interest in the determinants of firm survival, this time period, with its fast product cycles and ups and downs, is particularly appropriate. However, the software industry has experienced booms and busts throughout its history: it is cyclical and has upturns and downturns based on the dynamics of new technologies and economic conditions (Bokhari, 2007). In fact, based on historical data from Compustat for firms in the software industry, the long term failure rate for firms in the industry over the last fifty years is 14.6%, so the industry has always been volatile.

Our decision to focus on a single industry is consistent with that of management scholars who study the dynamics of firms in one industry (Henderson and Cockburn, 1994). Our approach is also in line with the assumption in the literature that firms in a four-digit standard industry category are horizontally interdependent and share one market (Kim, et al. 1989; Palepu, 1985; Pennings, 1981). Given the objectives of our study, our focus on a single industry provides a natural control for industry-specific factors and ensures that all firms are exposed to the same environment; since our interest is in the effects of firm-level factors, this is an essential control. In addition, given our interest in understanding the determinants of firm survival, it is important to study an industry where there are sufficient firm failures.

For the period of 1995-2007, we initially gathered data on 918 software firms. Of these firms, 48 firms were dropped because of missing data on more than three variables. For the remaining firms, we interpolated any missing values using traditional statistical approaches. Our final sample includes 870 software firms having various durations over the period of 1995-2007, for a total of 5,827 firm time-period observations. Six hundred four software firms are present in 1999 at the peak and 252 firms in 2007 at the lowest point. To determine whether our sample of software firms is representative of the population (publicly-held firms in the software industry from 1995-2007), we compared existing data from Compustat for the firms on ten accounting measures (sales, number of employees, cost of goods sold, accounts receivable, RD expenditures, selling expenditures, operating income, capital expenditures, assets, and working capital). We conducted two-sample t-tests of these measures for our sample and the population. The t-tests indicate that no significant differences exist in these measures, suggesting that our sample is representative of the population, at least along these dimensions. Also the firms in our sample account for 94.8% of the firms and 94.7% of the entire software industry sales during that timeframe. Therefore, we can conclude that the software firms in our study are representative of the industry, and that our sample captures key characteristics of firms in the industry.

In our study, we consider a firm to "fail" if it files for either Chapter 7 or Chapter 11 bankruptcy. A firm declares bankruptcy when it is unable to pay its debt. It may voluntarily or be forced to file Chapter 7 or Chapter 11 with a federal bankruptcy court for bankruptcy protection. Chapter 7 oversees the process of liquidation, while Chapter 11 governs the process of reorganization, implying significant uncertainty in survival.[5] Our use of bankruptcy filings to indicate firm failure is similar to other researchers of survival (Chava and Jarrow, 2004). We collected data on bankruptcy filings from the Reorganizations and

[5] Bankrupty laws changed in October 2005, making it more difficult for firms to file for Chapter 11 bankruptcy. However, the new law is believed to result in more firms converting from Chapter 11 to Chapter 7 liquidations. Since we also include Chapter 7 bankruptcy filings as a measure of failure, there is no effect on our results from this law. Once a firm in our sample has declared bankruptcy it does not re-enter the industry. Mergers and acquisitions are considered competitive moves in our study.

Liquidation modules of the SDC (Securities Data Company), CRSP (Center for Research in Security Prices) and Compustat Databases. There are 138 firms in our sample that failed during 1995-2007. Bankruptcy occurs relatively early in the life of a software firm. In our data, the average firm age at the time of bankruptcy is 9.6 years, and the median age at failure is 7 years.[6]

Except for patents and firm age, the data for the capabilities and control variables in our analysis are drawn from the Compustat database. Patents are obtained by searching each individual firm annually for patents in the United States Patent and Trademark Office (USPTO) website. Each firm's founding information was obtained through the Business and Company Resource Center in Infotrac. For competitive actions, we followed the approach developed in the competitive dynamics literature (e.g. Ferrier, et al. 1999), and initially collected 404,926 headlines and articles from trade journals for the 870 companies in the period of 1995-2007. The competitive actions were downloaded from Dialog (http://www.dialog.com/welcome/). Dialog provides online-based information services to information professionals using sophisticated search capabilities. The information provided includes databases of intellectual property, science and technology, news/trade journals and marketing research. The competitive actions were downloaded from the news/trade journals database in Dialog.

We developed a Java script to download and categorize the moves. Key words used in searching and examples of headlines for each competitive action are provided in the Online Supplement. Each article was automatically coded into the following competitive actions: innovation-related (marketing actions, pricing actions, product actions) and resource-related (operations actions, merger and acquisition actions and other capacity/scale actions). For each action, we saved firm names, dates, article titles and the sources of articles. To remove duplicates and ensure accuracy of the downloaded data, we randomly sampled 300 firms for each competitive action category in randomly selected years 2000 and 2005. The 300 firms comprise 100 large-, medium- and small-sized firms, respectively. After carefully screening for duplicates by hand and recording only the earliest chronological appearance of a particular news item, we

[6] In comparison, the average age at firm failure is 17.2 years, and the median age at failure is 14 years for banks (SIC=6020). For pharmaceuticals (SIC=2834), the average and median age at failure are 10.8 and 11 years, respectively. For computer hardware firms (SIC=3571), the average and median age at failure are 12.35 and 11 years, respectively.

obtained 15,341 non-duplicated competitive moves for the sampled firms in the sampled years. We then estimated twelve linear regression models (one for each firm-size and move category) to relate the manually screened (accurate) moves with the raw data downloaded from the Java scripts, the R-squared values ranging from 0.903 to 0.937 (see Online Supplement for details). Using the regression models, we adjusted the Java script downloaded data to arrive at more accurate move counts for each firm in each competitive action category for each year. Removal of duplicates reduced the total number of actual moves to 141,808. As a further test of the reliability of this approach, we manually screened an additional 130 firm-years of randomly sampled data from Dialog (competitive moves for 10 firms over 13 years) and validated these outcomes with the regression results. The test yielded a value of 0.91 which indicates a high degree of coding reliability.

Compared with the typical approaches for extracting and coding competitive moves in the competitive dynamics literature (e.g., Ferrier, et al. 1999), ours differs in two ways. First, given the scale and scope of the data, manual approaches to data collection and coding were impractical so we used an automated script. For large datasets such as that analyzed in our study, an automated script is much faster and more suitable than manual approaches. Various tests also found the script to have high reliability. Second, our approach aggregates moves into two basic categories – innovation-related and resource-related. The use of these two categories helps to distinguish whether a firm is more concerned with efficiency or innovation. Fewer categories also help us to achieve high reliability using automated coding. However, by subsuming moves into two categories, there is less detailed information about individual types of competitive moves, and it is not possible to identify how particular types of moves relate to performance. Overall, although text mining approaches such as the one we used in this study, may have some disadvantages when compared with manual approaches, they would nevertheless seem to offer a promising tool for collecting and analyzing extensive datasets on competitive moves by efficiently downloading information from databases and cleaning the data so that high accuracy can be achieved quickly (Fan, et al. 2006; Weiss, et al. 2004; Fabrizio, 2002).

4.2 Measurement of Variables

Table 1 provides descriptive statistics for the variables in our analysis. The pairwise correlations between the variables are provided in a correlation matrix in the Online Supplement. Unless otherwise indicated, each variable in our analysis is measured for firm i in time period t (the time period is demarcated in years such that each observation t represents a particular year).

Table 1: Variable Measures and Data Sources

(all accounting variables in $millions)					
	Variable *[data source]*	**Mean** **(Std Dev)**		**Variable** *[data source]*	**Mean** **(Std Dev)**
MK Capability	Sales Growth (y_{it}) *[COMPUSTAT]*	238.71 (1588.78)	**OP Capability**	Operating Income (y_{it}) *[COMPUSTAT]*	40.53 (617.67)
	SGA(t) (x_{1it}) *[COMPUSTAT]*	121.37 (679.82)		Cost of Goods Sold (x_{1it}) *[COMPUSTAT]*	65.99 (315.90)
	Receivables (x_{2it}) *[COMPUSTAT]*	51.70 (326.06)		Capital Expenditures (x_{2it}) *[COMPUSTAT]*	9.91 (56.79)
	Working Capital (x_{3it}) *[COMPUSTAT]*	125.03 (1337.81)		Employees (x_{4it}) *[COMPUSTAT]*	970 (3,961)
	Employees (x_{4it}) *[COMPUSTAT]*	970 (3,961)	**Control Variables**	Performance (Altman Z Score) *[COMPUSTAT]*	-0.14 (39.64)
	Installed Base (x_{5it}) *[COMPUSTAT]*	224.77 (1492.74)		Sectors *[Business & Company Resource Center in INFOTRAC]*	11% Visual, 66% Decision Support, 23% Infrastructure
RD Capability	Patents (y_{it}) *[USPTO website]*	1.31 (15.46)		Year in Sample *[COMPUSTAT]*	6.40 (3.44)
	Average RD Investment (x_{1it}) *[COMPUSTAT]*	26.85 (150.58)		Age (IPO year, Year since IPO) *[INFOTRAC]*	1994.95 (5.43), 5.63 (5.45)
	Employees (x_{4it}) *[COMPUSTAT]*	970 (3,961)		Growth rate in employees *[COMPUSTAT]*	0.386 (1.250)
				Size in assets *[COMPUSTAT]*	400.10 (3001.932)
Competitive Actions	Ratio of innovation-related moves to resource-related moves 1.29 (1.77) *[DIALOG]*				
Survival	Firm Bankruptcy Filing (for firm i at time t)$_{it}$ =138 or 15.9% of firms in our sample, or 15.03% of firms in population *[SDC, CRSP, COMPUSTAT]*				

Firm survival is our primary outcome and is measured using a binary variable; it is set to “1” if the firm exited the industry due to bankruptcy in that time period or “0” if not. The input and output variables for each firm’s capabilities are described next, and the computations of firms’ capability scores are described in the following section. *RD capabilities* relate RD outputs to RD inputs. We measure RD outputs in terms of patents. Counts of patents for each firm in each time period are first recorded, and then the cumulative average is computed for firm *i* at each time period *t* by: $\frac{\sum_{\tau=t_1}^{t} Patent_{i\tau}}{(t-t_1)+1}$, where t_1 is the first time period that firm data is available in our dataset and *t* is the current period. As described earlier, RD inputs include RD expenditures and employees. The cumulative average of RD expenditures up to time *t-1* (computed as $\frac{\sum_{\tau=t_1}^{t-1} RD\ Inv_{i\tau}}{t-t_1}$) is used as one input for measuring RD capability in time period *t*. This reflects a time lag of one period. We also examined the impacts of the cumulative RD expenditures at time *t-2* and *t-3* on patent outputs, and did not find a significant relationship. Therefore, a one period time lag is employed. The total number of employees in the firm at time *t* is used to measure $Employees_t$. *MK capabilities* relate marketing outputs to marketing input resources. We measure marketing outputs in terms of sales at time *t* and the four marketing inputs described earlier: SGA_t, Accounts $Receivable_t$, Working $Capital_t$, and $Employees_t$. No time lag is considered in measuring this capability, since there is no statistical significance in any lagged inputs. Finally, *OP capabilities* relate OP outputs to OP input resources. The output of operating capability is Operating Income, and its inputs are Employees, COGS, and Capital Expenditures. All of these inputs have the same period *t* as operating income.

For *type of competitive actions*, we computed the ratio of total innovation-related moves (e.g., sum of product and marketing moves) divided by the total resource-related moves (e.g., sum of capacity and scale, operations, service, mergers, and acquisition moves). This ratio reflects the relative emphasis placed by the firm on innovation actions.

Control variables in the analysis include firm *growth*, *age*, *size*, *sector*, *performance* and calendar *year*. *Growth* (employee growth rate) for each firm is measured in each time period in terms of the percentage of change in the number of employees in the firm over two consecutive years, i.e., $\frac{Employee_t - Employee_{t-1}}{Employee_{t-1}}$. Our use of change in employment to measure growth is consistent with other researchers (Davidsson, et al. 2006; Evans, 1987). Firm *age* is the date when the firm issued its Initial

Public Offering (IPO) (years since IPO as an alternative measure of firm age yields similar results). Firm *size* is its total assets in millions of dollars in that time period (Audia and Greve, 2006; Angelini and Generale, 2008; Moeller et al. 2004). *Sector* is distinguished according to the primary market segment for the firm's products into one of three sectors: Visual Applications (video games, entertainment systems and graphics software); Decision Support Applications (enterprise software, desktop applications, statistical software, and educational software) and Infrastructure Software (operating systems, development tools, network software, and security tools). Firm *performance* is measured using the Altman Z score. The Altman Z score is computed using Multiple Discriminant Analysis to combine a set of five financial ratios for each firm in each year. This score uses statistical techniques to predict a firm's probability of failure using variables from a firm's financial statements (Altman, 1968). The *years* between 1995 and 2007 are each coded using a binary variable which has a value of "1" if the data are for the particular year and "0" if not. 2001 is the base year in our analysis, as it is the year with the highest failure rate. Since the variables in our analysis are measured using different units, to ease interpretation, we standardized them to means of zero and standard deviations of one.

4.3 Estimating Software Firms' RD, MK and OP Capabilities

A key challenge to empirical studies of the RBV is the difficulty of conceptualizing and measuring capabilities. In our study, we have drawn upon the approach of Amit and Schoemaker (1993) and Dutta, et al. (2005, 1999) to conceptualize capabilities as the ability of a software firm to transform its input resources into outputs, relative to its peers. Dutta, et al. (2005, 1999) use stochastic frontier estimation methodologies to measure firms' capabilities. If a capability can be viewed as a transformation process, a stochastic production function can be used to measure the relative efficiency of a firm for that capability, with respect to its peers, in converting the respective inputs into outputs. A stochastic production function shows the level of output that can be produced from a given level of inputs. The function relates the resources used by a firm to achieve its objectives to the best the firm could have done if it had used the resources efficiently. It computes an efficiency score ranging from 0 to 1 to reflect the level of a firm's relative efficiency in transforming inputs into outputs in which "0" reflects the lowest level of efficiency and “1” represents the optimal level of efficiency in the transformation process for the firms in the sample. The boundary or “frontier” of a stochastic production function is formed by “best practice” firms, which represent the maximum potential output that can be achieved by the firms in the sample for a given set of inputs. Firms producing at levels inside the estimated production frontier are deemed “inefficient”. The efficiency of a firm is computed relative to the efficiency of other firms in the sample. For example, a software firm with a higher RD capability in a particular time period would have a higher efficiency score than a software firm with a lower RD capability in that time period (the score of the efficient firm would be “1” if its transformation process is the most efficient of the firms in the sample).

In our study, we adopt a stochastic translog production function (Battese, et al., 2000, Meeusen and van den Broeck, 1997, Kumbhakar and Lovell, 2000, and Aigner, et al. 1977) to estimate the relative efficiency or capability for RD, MK and OP of each software firm in our sample. That is, we compute an efficiency score using this approach for each firm, for each capability, in each time period the firm is operating. Details about the approach and computation and the average capability scores for all firms, for surviving firms and firms that failed are provided in the Online Supplement.

The average capability scores for MK capability and RD capability of the software firms in our sample over all time periods are 0.85 with a standard deviation of 0.13, and 0.86 with a standard deviation of 0.14, respectively. This implies that most software firms generally operate close to the optimal frontier in the MK and RD functions, but it does not necessarily imply that software firms are more capable in MK and RD than in OP. Because the comparison among firms in each function is based on Pareto theory (relative comparison), the high average MK and RD capability scores only indicate that in MK and RD, most software firms are similar in comparison with the best ones. On the other hand, OP capability has an average score of 0.41 with a standard deviation of 0.23. This indicates that many software firms operate farther away from the efficient frontier in OP and are significantly different in OP capability.

4.4 Firm Survival Analysis

Although survival analyses originated in the medical field, they are increasingly applied in economics, engineering, and social sciences (Hosmer and Lemeshow, 1989). For example, Randall, et al. (2006)

conducted a survival analysis of Internet retailers and found that those firms making inventory ownership decisions in line with strategic factors are less likely to go bankrupt than those making inconsistent inventory choices. The hazard rate, *h(t)*, refers to the failure rate of a subject per unit of time; in our study, this is the failure rate of a firm in a year. It is a transformation of the survival function, *S(t)*, which is *1 – F(t)* where *F(t)* is the cumulative distribution function of the time to failure. Alternatively, the hazard rate that is closely related to *S(t)* is given by the following formula:

Hazard Function $\equiv$ conditional failure rate

$$h(t) = \lim_{dt \to 0} \frac{P(t < T < t + \Delta t \mid T > t)}{dt}$$

The hazard function, *h(t)*, provides the *instantaneous failure rate* that a firm having not failed up to time *t* will fail during the infinitesimally small interval *(t + Δt)*. If time is viewed as discrete rather than continuous, then any age specific rate is called a hazard rate that can range between 0 and infinity depending on the time unit used. In this study, we adopted the Cox proportional hazards model (Cox PH) (1972) since it is the most general and robust regression model and does not make any assumptions concerning the nature or shape of the underlying survival distribution. The model is expressed as:

$$h(t, \boldsymbol{x}) = h_o(t)e^{\sum_{i=1}^{P} \beta_i x_i} \text{ with } \boldsymbol{x} = (x_1, x_2, ..., x_P)$$

where x is a vector of explanatory variables and β_i is the parameter to be estimated for $i = 1, .., P$. The hazard rate at time t in the Cox PH Model is a product of two quantities. The first, $h_0(t)$, is the baseline hazard function, and the second is the exponential expression e to the linear sum of $\beta_i x_i$, where the sum is over the P explanatory x variables. An important feature of the Cox model is that it assumes proportional hazards (PH), i.e. the baseline hazard model is a function of t and does not involve the *x's*. In general, a hazard rate can be computed by the hazard of one firm divided by the hazard of another firm. The two firms being compared can be distinguished by their values for the set of predictors, that is, the *x's*. So the hazard rate is the estimate of $h(t,x^*)$ divided by the estimate of $h(t,x)$, where x* denotes a vector of predictors for one firm and x for the other as below:

$$\overline{HR} = \frac{\hat{h}(t,x^*)}{\hat{h}(t,x)} = \frac{\hat{h}_o(t)e^{\sum_{i=1}^{p}\beta_i x_i^*}}{\hat{h}_o(t)e^{\sum_{i=1}^{p}\beta_i x_i}} = e^{\sum_{i=1}^{p}\hat{\beta}_i(x_i^* - x_i)}$$

Suppose two firms A and B have three variables: capability, competitive actions, and interaction between capability and actions. All three variables are standardized with means of 0 and standard deviation of 1. Now assume Firm A has the vector of x^***:** $x^*_1 = 1$, x^*_2 = competitive actions and x^*_3 = 1 x competitive actions and Firm B has the vector of x: $x_1 = 0$, x_2 = competitive actions and x_3 = 0 x competitive actions. When the value of competitive action is the same in x^* and x, the hazard rate adjusted by the competitive actions can be computed as below:

$$\overline{\mathrm{HR}} = e^{\sum_{i=1}^{p}\hat{\beta}\left(x_i^* - x_i\right)} = e^{\{\beta_1(1-0)+\beta_2(comp-comp)+\beta_3(1*comp)-\beta_3(0*comp)\}} = e^{\beta_1+\beta_3*comp}$$

If the result above is less than 1, Firm A has a smaller hazard rate, or likelihood of failure, than Firm B. Otherwise, Firm B has a smaller hazard rate. Generalizing the above equation, we are able to assess the impact of each capability and the interaction between the capabilities and actions on firm failure rates.

5. Results

5.1 Results from Firm Survival Analysis

To evaluate firm-specific variables and covariates as determinants of firm survival, we use a four-stage, nested hierarchical estimation procedure. This allows us to compute the incremental significance of the variables added at each stage. Our first stage is a model with only the standardized control variables of firm size, age, growth, sector, performance and year. In the second stage, three standardized capability variables are added. In the third stage, we add the standardized measure of competitive actions. Finally, the interactions between competitive actions and the three capabilities are added in the full model. Table 2 reports the maximum likelihood estimates of the parameters for the full model (the results for the first three stages are reported in the Online Supplement). Column 1 in Table 2 lists the variables. The second column gives the estimates of the parameters corresponding to each variable. Column 3 shows the standard errors of the estimated regression coefficients, while Column 4 provides Z values and column five shows the p-value of significance test. The last column, “Haz. Rate”, corresponds to the effect of each variable on the hazard rate controlling for other variables in the model.

5.2 Results from Hypothesis Tests

Hypothesis 1 argued that higher MK and RD capabilities will reduce firm failure rates more than higher OP capabilities. As shown in Table 2, the estimation yielded different coefficients for MK, RD and OP capabilities, with values of -0.248, -0.108 and -0.730, respectively, which implies that the impacts of the three capabilities on firm survival differ. However, given the coefficient values, we cannot conclude that MK and RD capabilities are more important for firm survival than OP capability. Indeed, Wald tests indicate that *OP capability* has a stronger effect on firm survival than MK capability ($\chi^2 = 13.62$, $p < 0.001$, df = 1) and RD capability ($\chi^2 = 28.9$, $p < 0.001$, df = 1). This contradicts our Hypothesis 1 that higher MK and RD capabilities would reduce the likelihood of firm failure more than higher OP capability (in fact, the opposite is true). Thus, Hypothesis 1 is rejected.

Table 2: Survival Model Results

Variables	Coefficient	Std. Err.	Z	P > | z |	Haz. Rate
1995	-0.511	1.211	-0.42	0.673	0.600
1996	-2.554	0.634	-4.03	0.000	0.078
1997	-1.649	0.543	-3.04	0.002	0.192
1998	-1.952	0.583	-3.35	0.001	0.142
1999	-0.255	0.419	-0.61	0.543	0.775
2000	-0.267	0.414	-0.65	0.518	0.765
2002	0.382	0.367	1.04	0.299	1.465
2003	0.192	0.465	0.41	0.680	1.211
2004	-1.527	0.677	-2.26	0.024	0.217
2005	0.784	0.789	0.99	0.320	2.191
Decision Support Applications	-0.282	0.200	-1.41	0.158	0.754
Visual Applications	-0.312	0.290	-1.07	0.282	0.732
Size	-0.492	0.084	-5.86	0.000	0.612
Growth	-1.718	0.587	-2.93	0.003	0.179
Altman-Z	-0.019	0.049	-0.39	0.694	0.981
Year	-0.126	0.032	-3.98	0.000	0.881
Age	-0.036	0.015	-2.43	0.015	0.965
MK	-0.248	0.068	-3.62	0.000	0.781
OP	-0.730	0.135	-5.42	0.000	0.482
RD	-0.108	0.054	-1.99	0.046	0.897
Innovation-to-Resource-Moves	-0.558	0.163	-3.42	0.001	0.573
Moves x MK	-0.176	0.068	-2.58	0.010	0.839
Moves x OP	-0.275	0.164	-1.68	0.094	0.760
Moves x RD	0.240	0.093	2.58	0.010	1.271

In ***Hypothesis 2***, we evaluate whether firms that emphasize innovation-related competitive actions have lower firm failure rates than firms that do not. To evaluate if the type of competitive actions is significant in explaining incremental variation in firm failure, we use a likelihood test to compare nested models without and with competitive actions and find that $\chi^2 = 7.123$, $p = 0.008$, df = 1, which indicates that over and above the effects of other variables in the model, the type of competitive actions significantly explains variations in firm failure rates. To evaluate our Hypothesis 2 we differentiate the full model in Table 2 with respect to competitive actions, and hold the other variables at their means; this yields a coefficient for innovation-related competitive actions of -0.558 which is significant at $p < 0.001$. As hypothesized, firms that emphasize innovation-related competitive actions have lower firm failure rates. Thus Hypothesis 2 is supported.

Finally, in ***Hypothesis 3***, we test whether firm survival is affected by the interaction between capabilities and competitive actions. Our interest in Hypothesis 3 is how different levels of capabilities affect the survival of firms initiating different types of competitive actions. To evaluate this hypothesis, we use the coefficients for the variables in the full model in Table 2 to compute four types of hazard rates: (i) when innovation-related competitive actions and MK, RD and OP are all at high levels (defined as one standard deviation above the mean values); (ii) when capabilities are low (defined as one standard deviation below the mean values) but innovation-related competitive actions are high; (iii) when capabilities are high but innovation-related competitive actions are low; and (iv) when both capabilities and innovation-related competitive actions are low. We find that, when MK capability is high and firms initiate more innovation-related actions, the firm failure rates are reduced from 0.78 (see the rightmost column in Table 2) to 0.654 (= $e^{-0.248-0.176}$), a reduction of 17%. Similarly, when both OP capability and levels of innovation-related actions are high, the hazard rate is reduced from 0.482 to 0.366, a 24% improvement. In contrast, when both RD capability and levels of innovation-related actions are high, the hazard rate is increased from 0.897 to 1.141 (an increase of 27%). On the other hand, at high levels of innovation-related activities and low levels of MK capability, the firm failure rate increases from 0.781 to 1.528 (= $e^{0.248+0.176}$) or 95.6%. Similar results are obtained for OP capability, and the hazard rate increases from 0.482 to 2.732 (or 466%) when the level of innovation-related competitive actions is high but OP capability is low. In contrast, the firm failure rate decreases from 0.897 to 0.876 (a reduction of 2.3%) when the level of innovation-related competitive actions is high but RD capability is low.

The results provide sufficient evidence to partially support Hypothesis 3: firms that initiate more innovation-related competitive actions and that have higher capabilities in MK and OP have significantly lower failure rates, but firms that initiate more innovation-related activities but with lower capabilities in MK and OP have higher failure rates. Conversely, firms that initiate more resource-related activities and that have higher capabilities in RD have lower failure rates. Specific competitive actions and capability interactions are discussed in the next section.

6. Discussion

We first discuss the results for the hypotheses. We then describe and discuss a post hoc analysis of capabilities, competitive actions and firm performance and survival by sector within the software industry.

6.1 Discussion of Hypothesis Test Results

With respect to firm capabilities, we found that OP capability has the strongest positive impact, while MK and RD capability have a significant but lower degree of impact on firm survival, contradicting Hypothesis 1. In contrast to Dutta et al. (1999) and Hall et al. (2005) who maintain that MK and RD capabilities are the key determinants of the market value of high-tech companies, we found that increasing OP capability may improve a software firm's chance of survival the most. In the last column of Table 2, we note that the hazard rate of OP controlling for other variables is 0.482, while those of MK and RD are 0.781 and 0.897, respectively. This implies that the reduction in the likelihood of firm failure due to a one standard deviation increase in MK, OP or RD capabilities is 21.9%, 51.8% or 10.3%, respectively. The impact of OP capabilities on firm failure rates is almost twice that of MK and five times that of RD. This result seems to contradict the assumption that RD and MK capabilities are most critical to firm success in the high-tech firms.

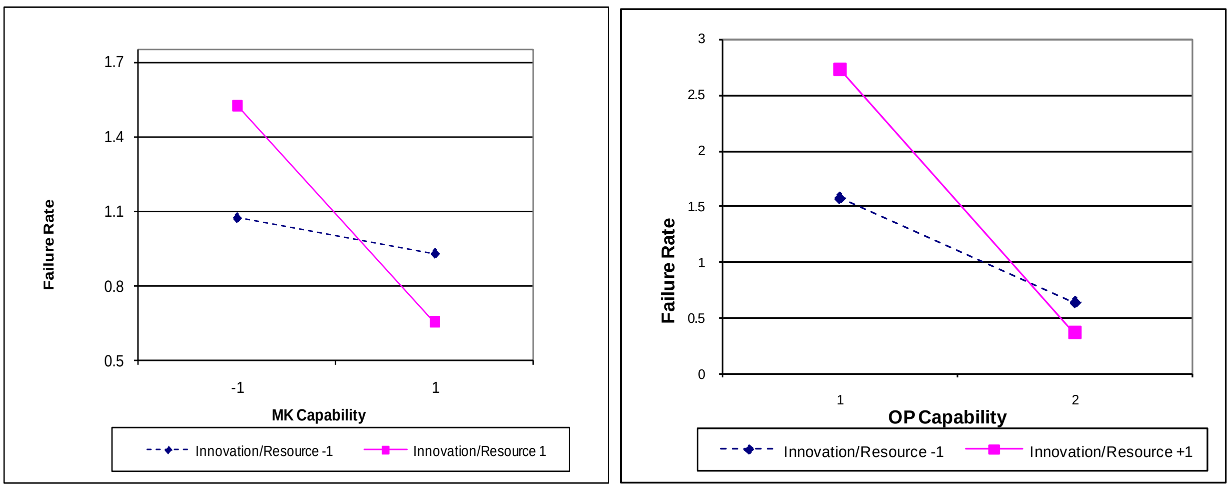
To further explore this result, we compared the average efficiency scores for each capability for failed versus surviving firms in each year (details are in the Online Supplement). The OP capability scores for the failed firms are always below those of the surviving firms in every year during the time period of our study; this difference in means across the years is significant (mean OP Failed = 0.30, mean OP Surviving = 0.41, difference = 0.11, $t = 5.785$, $p < 0.001$). In contrast, for RD and MK capabilities, there are numerous years when there are no significant differences in efficiency between the failed and surviving firms. In particular, the RD capabilities of the failed and surviving firms are quite similar, with no significant differences in any year. This suggests that although MK and RD functions are clearly important, such capabilities alone may not be as immediately critical to software firm survival as OP capability. Comparing firms with high OP (top 25th percentile) to low OP (bottom 25th percentile) further supports the importance of OP capability: the firms with low OP fail at five times the rate as those with high OP capability. This difference is significant at $p < 0.001$. The importance of operational excellence is highlighted by the author of a new book on entrepreneurs (McFarland, 2008, p. G6):

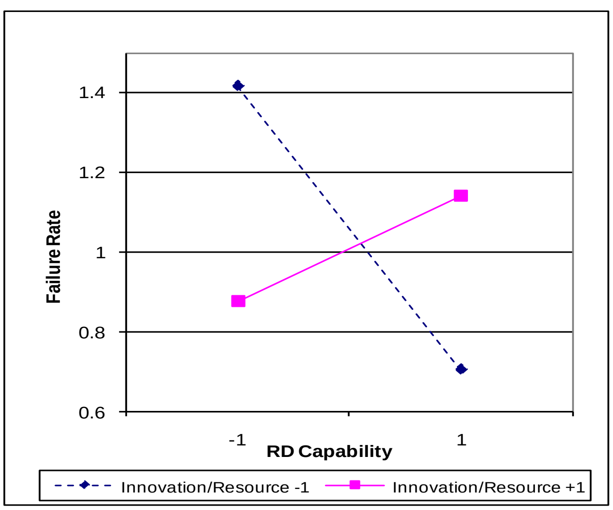
> *"…contrary to what most people imagine, most new businesses are not started with risky, new-to-the-world ideas like those of eBay and Google, which promise to transform the way we buy things. Cook (co-founder of Intuit) reported that when his company launched its Quicken software program, there were already 46 similar products on the market - causing him to joke, 'We enjoyed 47th mover advantage'. Columbia University business professor Amar Bhide found that only 12% of growth company founders surveyed attribute their success to an unusual or extraordinary idea;* ***88% reported that their success was due mainly to <u>exceptional execution</u> of an ordinary idea****."* (emphasis ours)

With respect to the type of competitive actions and the interactions between competitive actions and capabilities, we have several interesting findings. Hypothesis 2 posited that firms which initiate more innovation-related competitive actions have lower firm failure rates, and this hypothesis is supported. A comparison of the average ratio of innovation-related to resource-related competitive actions for failed versus surviving firms in each year indicates that the surviving firms emphasize innovation-related moves significantly more than the failed firms in each year, making more than twice the number of innovation-related moves of failed firms (details are in the Online Supplement). This difference in means is significant (mean ratio of innovation-related to resource-related moves for Failed = 0.83, mean ratio of innovation-related to resource-related moves for Surviving = 1.30, difference =0.47, $t = 3.063$, $p < 0.002$).

The results for Hypothesis 1 and Hypothesis 2 taken together imply that firms making more innovation-related moves *and* that can efficiently execute those moves are significantly better off in terms of enhanced survival. The interaction effects posited in Hypothesis 3 provide formal support for this insight. In Hypothesis 3, we theorized that a greater emphasis on innovation-related moves increases the likelihood of survival even more for firms with higher levels of capabilities but not for firms with lower levels of capabilities. Our results support this hypothesis, but in a more nuanced way than we anticipated. Figure 3 illustrates the interaction effects between competitive actions and the three capabilities.

Figure 3: Interactions between Competitive Actions and Capabilities





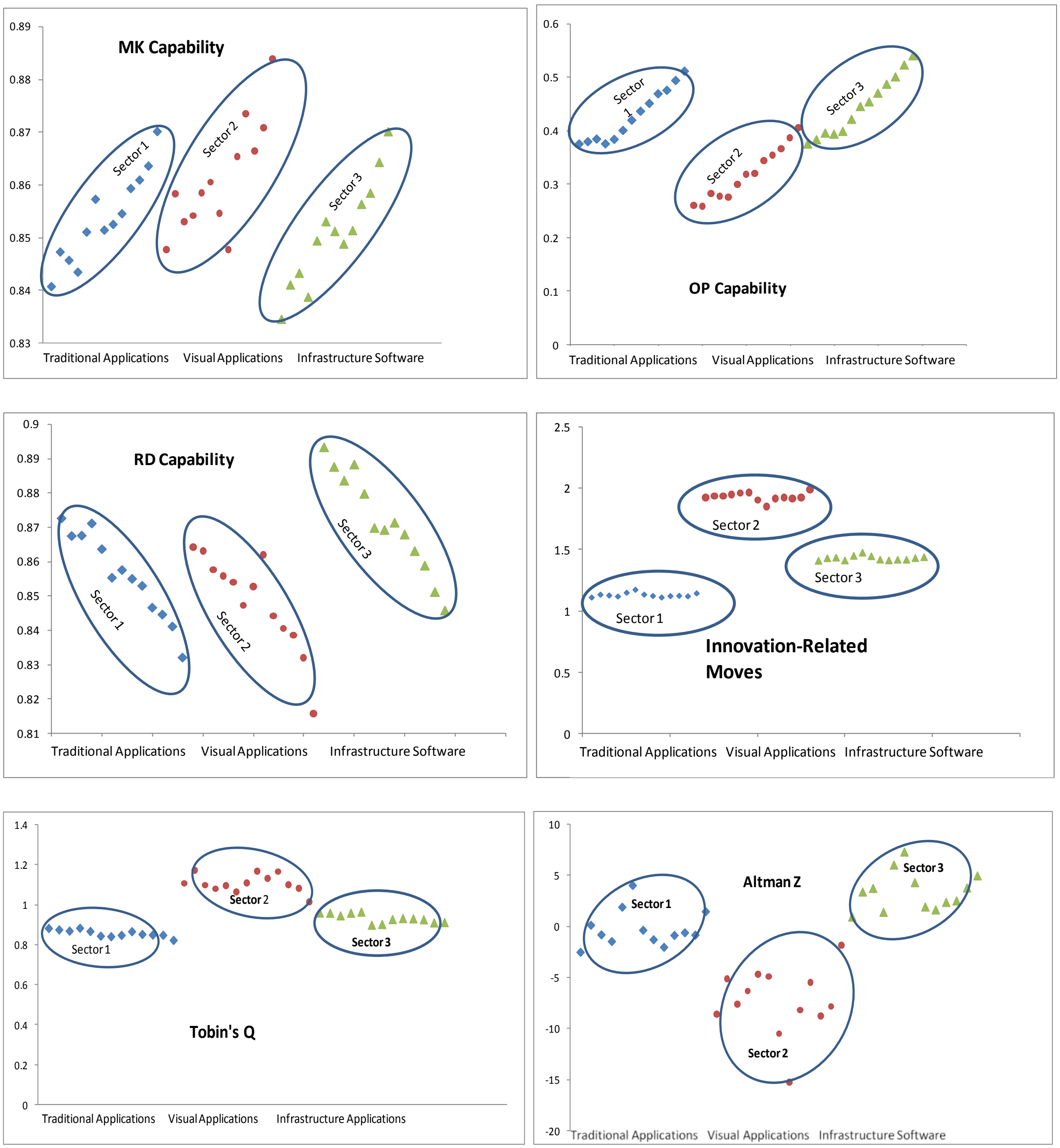
As can be seen in Figure 3, at high levels of MK and OP capabilities, a greater emphasis on innovation-related competitive actions reduces the likelihood of firm failure significantly more than at a lower emphasis on innovation-related competitive actions, or at average levels of capabilities. Figure 3 also suggests that a greater emphasis on innovation-related competitive actions does not appear beneficial for firms with lower MK and RD capabilities. Rather, when inefficient firms place too much emphasis on innovation actions, the chances of failure appear to increase tremendously. Finally the interaction between competitive actions and RD is significant but in a direction opposite from that hypothesized, suggesting that higher RD capabilities complement resource-related competitive actions, rather than innovation-related competitive actions. This suggests that innovation-related competitive actions complement MK and OP capabilities while resource-related competitive actions complement RD capabilities and enhance the capabilities' positive effects on firm survival. An explanation for these findings is that firms emphasizing innovation-related actions will be more effective when they can implement those actions with higher levels of MK and OP capabilities. In contrast, firms emphasizing resource-related actions such as mergers and acquisitions can capitalize on those actions when they have higher innovative capabilities, represented by higher RD capabilities. These findings contribute to the literature by showing that competitive actions or capabilities alone are not sufficient to explain survival, and that the effects of different types of competitive actions are tempered by the level of a firm's MK, RD and OP capabilities in their influence on the firm's continued existence.

6.2 Post Hoc Analysis of Firm Sectors

To provide a deeper understanding of firm survival in the software industry, we conducted a post hoc analysis of capabilities, competitive actions and firm survival in different sectors of the software industry. Sector 1 includes traditional decision support applications such as desktop productivity suites, statistical software, accounting, payroll, and enterprise resource planning systems. Sector 2 includes highly visual applications such as video games and graphics software. Sector 3 includes infrastructure software including operating systems, security tools, and software development tools. As noted by software industry analysts, the competitive dynamics in each of these sectors are quite different given the maturity of products in the sector with Sector 3 being the most mature and with Sector 2 the least mature and having the shortest product life cycles (Bokhari, 2007).

We conducted a multiple analysis of covariance (MANCOVA), comparing mean capabilities, competitive actions, firm survival and measures of firm financial performance (the Altman Z and the Tobin's q) across the sectors, controlling for firm size, age, growth and year of analysis. Figure 4 graphically illustrates the results, showing the annual averages by sector. As can be seen in Figure 4, Sector 2 (visual applications) has the highest level of MK capability, but the lowest levels of OP and RD capabilities; Sector 2 firms also have the highest emphasis on innovation-related competitive actions. In terms of financial performance, Sector 2 firms have the highest value for Tobin's q, but also the worst Altman Z score. In contrast, Sector 3 (infrastructure software) has the highest OP and RD capabilities, while Sector 1 (traditional decision support applications) has intermediate levels of capabilities, and the lowest level of innovation-related moves.

Figure 4: Differences in Capabilities, Competitive Actions and Performance Across Sectors



In terms of firm failure, Sector 2 has more failures than expected, Sector 1 has fewer failures than expected, and Sector 3 has about as many failures as expected. This suggests that firms producing highly visual software like video games are especially good at marketing and make more innovation-related moves than resource-related moves. This may be appropriate given the fast pace of competition and the short life span of "hit" products in this sector. Further, firms producing visual applications are highly valued in the market (highest Tobin's q) but are also the riskiest (worst Altman Z), perhaps due to the high risk / high value nature of the products they produce. In contrast, firms producing the traditional software applications (e.g., enterprise systems, desktop suites) have intermediate levels of capabilities and make more resource-related moves than innovation-related moves. These firms are valued the least in the market (lowest Tobin's q) and are intermediate in risk (intermediate level of Altman Z). Finally, firms producing infrastructure software have the lowest MK capability, but are the best in OP and RD capabilities. Due to economies of scale from longer product life cycles, these firms are especially good at recovering their investments in RD and are very efficient in OP. Sector 3 firms are the least risky (highest value of Altman Z), and are valued less than the Sector 2 firms producing visual applications but more than the Sector 1 firms producing the traditional software applications. The Sector 3 firms also make more innovation-related moves than the Sector 1 firms producing traditional software but less than the Sector 2 firms producing visual applications.

There are two implications of this post hoc analysis. The first is that firms appear to "match" their capabilities and competitive actions to the particular dynamics of their immediate market segment, and the second is that the length of the product life cycle may be a key characteristic influencing how firms make this match. Firms producing short cycle products (such as visual applications) that do not last in the market must be extremely competent at marketing and may emphasize MK over OP efficiency. Given the potential for big hits (but also big misses) in this sector, these firms are risky in terms of financial fitness but are highly valued in the market. Firms producing long life cycle products (such as infrastructure software) must be very good at OP and RD. Given the length of product life cycles and the "entrenchment" of market leaders in this segment, the firms are the least risky. Firms making traditional software applications are somewhere in between as their products have a medium life cycle. Further research would be useful to verify these findings in other industries.

7. Conclusion

Our research is the first to integrate capability, competitive actions, and firm survival and examine their inter-relationships. However, our work has some limitations. First, we have focused on MK, RD and OP capabilities. There may be other capabilities that are relevant for firm survival and competitiveness such as agility, innovation and reputation (Holsapple and Singh, 2001). Second, our results are based on the data in software industry, and as such, may not generalize to other industries. Third, due to the large sample size, our study does not explore software firm-specific characteristics such as knowledge-base, talented workers, product categories and specialized facilities which might afford niche advantages in dynamic competition. Finally, our study does not explore the impact of network alliances on firm survival.

For management practice, our results suggest the importance of OP capability for firm survival in the software industry. While managers of a software firm may focus on innovation, our study underscores the importance of operational efficiency in helping the firm to persist. In addition, our study shows that competitive actions have more impact if they are supported by strong capabilities, so managers who want to improve their firms' competitiveness should focus on synergies between capabilities and actions.

Future research could include studies to generalize our findings in different industries and to examine the impact of firm-specific characteristics on firm survival by focusing on specific firms or product categories. Large-scale empirical studies of networks and alliances among software firms can also be an interesting extension of our current research.

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